ENGINEERING'S ROLE IN THE EVOLUTIONARY UNDERSTANDING OF COMPLEX SERVICE SYSTEMS

Abstract: *In the United States, over 70% of the labor force is engaged in services, and an estimated 75% of the GDP in 2005 was derived from services. Industrialized countries around the world share similar statistics, while emerging economic powers, such as India and China, are seeing dramatic growth in their service economy. The service sector has evolved from a low-skill, labor-based position to one where high-skill professional services, particularly business-to-business services, are a leading driver of innovation, accelerated business globalization, and economic disruption. This rapid shift, due to the complex and inter-disciplinary nature of service system design, deployment, support and evolution, has resulted not only in a gap between the practice, definition and science of service systems, but also in a need for service scientists who are able to understand that complexity, design solutions that address the complexity, and evaluate those solutions in light of the complexity. This talk will summarize the state of service economy and discuss the case for a science of service systems as well as the need for engineering disciplines to participate in the evolution of complex service systems.*

Service Defined

A service is defined as the application of skills and knowledge for the benefit of another (Terrill & Middlebrooks, 2000). Where, the service may manifest as a process, standardized description, protocol or a negotiation of these base artifacts. A typical service requires participation and input from both the client and the provider, resulting in the co-creation (or co-production) of some valued tangible or intangible asset (e.g., a good or improved customer satisfaction of the client's clients). The client owns or controls some state that the provider transforms according to an agreement established between both parties that describe the negotiated terms of the interaction (Spohrer, Maglio, Bailey & Gruhl, 2007).

The process of transformation in service results in a modification of the client's possessions, processes and/or tangible assets. Operationally, we take the view that a service is an action that one organization does (with and) for the benefit of another (and themselves). There exists a service contract that describes what is to be done, defines what services will be carried out, how they will be used, under what conditions, the monies to be paid, associated incentives, deliverables and results. Providers and clients may be individuals, firms, government agencies or a myriad of different organizations of people and technologies, which may result in a complex network of value. Everyone in the network works in a myriad of ways to create value. This paper describes the need and opportunity for the engineering domain to participate in service systems and the service economy.

The Service Economy

In the United States, over 70% of the labor force is engaged in services, and an estimated 75% of the GDP in 2005 was derived from services. This phenomenon is global, with industrialized countries around the world showing similar trends, while emerging economies, such as India and China, as well as developing economies, such as Nigeria and Ghana, are seeing dramatic growth in the service sector. Over time, the service sector has taken different forms from pre-industrial revolution high-skilled, labor-based craftsmanship to post-industrial revolution low-skill, labor-based services. However, the service sector has shifted again where a service economy is resulting in opportunities where high-skill professional services, particularly business-to-business services, are a leading driver of innovation, accelerated business globalization and economic disruption.

The shift to a service economy is rapidly occurring, due in part to the growth and ubiquity of technology in our everyday lives, which supports and enables inter-disciplinary interactions and exchange. This, in turn, has resulted in a need for service practitioners and scientists who understand the nature of services and are able to articulate, capture, simulate and optimize on the complex and inter-disciplinary nature of service system design, deployment and continued evolution.

Service Systems Thinking

A service system is "any number of elements, interconnections, attributes and stakeholders interacting in a co-productive relationship that creates value", where services are "intangible activities customized to the individual request of known clients" (IBM Corp, 2007, p. 2; Pine & Gilmore, 1999). Service systems can be described as socio-technical systems that are similar to manufacturing and economic systems in that all three systems include elements, interconnections, attributes and stakeholders represented in terms of input, throughput and output process models (IBM Corp, 2007). However, service systems also include a feedback loop into the input that defines the service engagement, in which the client and provider interact in such a way that they co-create value for all parties. This notion of co-creation of value is what differentiates a service system from other types of business process systems (e.g., traditional supply chain) and its features and impacts are not fully understood at this time.

Sampson's (2004) Model of Unified Services Theory describes the distinction between traditional systems, like manufacturing and economic systems, and service systems (Figure 1). In the former, while the consumer may drive or inform the requirements, they are not actually engaged in the design, implementation or manufacturing of the output. Instead, the consumer's role is to select and consume the output (Sampson, 2001). In service systems, however, the consumer, along with the provider, provides inputs into the process itself that impacts the production process and affects the final output (IBM Corp, 2007). The final output of a service system may be tangible or intangible. Examples of tangible outputs are goods such as automobiles or a product such as customized code, while an example of an intangible output is increased return on investment for the client due to business process redesign.

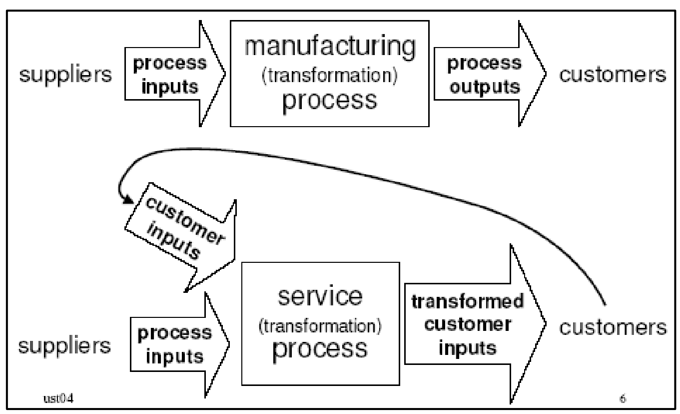

Figure 1. Sampson's Model of Unified Services Theory (Sampson, 2004, p. 6).

Fitzsimmons and Fitzsimmons (2003) extend Sampson's Model of Unified Theory by suggesting that the service consumer not only provides input to the service system, but actually is an input to the service system that is "transformed by the service process into an output with some degree of satisfaction" (p. 29). Examples include airlines, in which customers, as well as their baggage, are inputs; or education, in which consumers provide their minds. Whether the service consumer is considered a provider of input or as input itself, the enactment of a service is a process of transformation that results in a modification of the client's possessions, processes or tangible assets. However, this transformation involves complexity with respect to the types of inputs (customer, process, etc.), understanding and managing the transformation process (which often involves very complex interdependencies and complex arrangements of nested systems), and assessing outcomes that are both used by service consumers to evaluate their service experience as feedback into the service system.

Engineering's Participation

In talks that Jim Spohrer of IBM (personal communications, 2007) gives on the Service Science, Management and Engineering (SSME) initiative, he speaks of four major service system challenges. The challenges are the understanding and creation of:

- theoretical frameworks to determine what of principles define and explain service system phenomena;
- empirical frameworks to guide experimentation and define system parameters or constructs around service system phenomena;
- analytic frameworks that apply mathematical models to service system constructs; and
- design and engineering frameworks to understand the practical payoff from science and construct innovative solutions within service systems.

Given these challenges and the ideas described in the previous sections, there is a lot of work to be done at many levels of investigation, learning and investment to understand, model and optimize services. With that said, the focus for this paper is the last challenge, *design and engineering frameworks*, and what that means to engineering programs and the engineering domain. This section will concentrate on providing some clarity for this challenge within engineering.

A question often asked of us who are exploring services is 'what does this mean for education and skill development?' Themes that arise around service education include multidisciplinarity, interaction, co-creation/co-production and systems thinking. Let's first consider ideas proposed by Bryson, Daniels and Warf (2004) around organizing production. They discuss the transformation of manufacturing to service work and the relationships production and consumption of services within a service economy paradigm. Part of their argument is that, "the production of goods and services should be conceptualized as a complex network of interactions between different functions with the result being the creation of a product or the delivery of a service. …. Manufactured products inspire the development of new services as well as new physical products" (p. 51). They go on to discuss how manufacturing (e.g., design and manufacture of consumer goods to the built environment) and services (e.g., finance, insurance, delivery, maintenance) are becoming increasingly complimentary and mutually supporting activities. Taboul (2007) also writes of the relationship between what he calls *professional services* and *industrialized services*. Where, this relationship creates opportunities for 'product plus' innovations and offerings. It is beyond this paper to explore the different forms of production organization and product plus models, but instead to note that these evolving relationships will have implications for engineering education and practice.

A general starting point to understand some of the implications for education and practice has been explored as part of the Cambridge Service Science, Management and Engineering Symposium (2007) conducted on service innovation. A consortium of academic and industry leaders provide a common language for services to be used across disciplines and outline approaches to bridge gaps in academics in support of knowledge and skills development for services. They recognized the difficultly in evolving a complex educational topic such as service science and provide three pathways for university programs to consider: (1) 'super' multi-disciplinary, (2) multi-disciplinary and (3) inter-disciplinary.

The output from the Symposium provides general guidance for service education. However, academics in engineering are also providing early advice and examples of how their programs are evolving to address skills needed for the service economy. Such as and article by Ganz (2006), where he identifies structure, process and outcome as three key areas for engineering research and education leadership in services. That engineering models for these constructs can be used to close gaps between service ideas and realization and provide an evolutionary path for engineering.

Tien and Berg (2003) have proposed the development of a branch of systems engineering focused on service systems. In this, they conclude that there are many areas in design, production and delivery that still need to be explored and that the multidisciplinary nature of services has to be evinced. Larson (2008), on the other hand, states that “to design and operate service systems for today and tomorrow, a new type of engineer must be educated, one who focuses on services rather than manufacturing. Such an engineer must be able to integrate three sciences—management, social, and engineering science—in the analysis of service systems” (p. 41).

Larson goes on to reinforce this idea by making the distinction between ‘engineering systems’ (which is the goal for service systems) and ‘systems engineering’. Where, engineering systems for services is at the intersection of engineering, management and social sciences; and that systems engineering tends to focus on the technical or manufactured elements within a system, tending to leave out the business and human aspects. In his argument, he provides detailed descriptions of six ongoing projects at the Center for Engineering Systems Fundamentals (CESF) that emphasize this engineering systems approach (Figure 2).

Research Topic Area	Engineering Science	Management Science	Social Sciences
Demand management for critical infrastructures	Electrical and systems engineering	Planning large capital investment projects; maintaining systems	Understanding cost-benefit relationships for users in order to shave peak demands
Voting systems	Operations research of queuing	Managing the pre-election day deployment and real-time re-deployment of resources	Understanding voters' decision to abandon voting lines
Social distancing in influenza pandemic	Modeling the physics of disease progression	Planning responses of government, businesses, and families	Understanding and managing human behavior in the presence of a pandemic
Hurricane preparedness and response	Modeling the physics of hurricane progression	Managing evacuations and related responses	Understanding people's propensity to follow evacuation orders

Figure 2. Components of engineering, management and social sciences in CESF initiatives (Larson, 2008, p. 43)

Summary

There is a need for engineering to participate in the evolving service economy. Through examples of recent thought leadership around service definition and education, this paper provides a perspective on the challenges and opportunities for engineering education and continued skill development.

References

Bryson, J.R., Daniels, P.W., & Warf, B. (2004). *Service worlds: People, organizations, technologies.* New York: Routledge.

Fitzsimmons, J.A. & Fitzsimmons, M.J. (2003). *Service management: Operations, strategy, and information technology* (4^{th} ed.). New York: McGraw-Hill.

Ganz, W. (July, 2006). Germany: Service engineering. *Communications of the ACM, 49*(7), 79.

IBM Corporation. (2007). *SSME: Systems*. Available at http://www-304.ibm.com/jct09002c/university/scholars/skills/ssme/resources.html

Larson, R.C. (2008). Service science: At the intersection of management, social, and engineering sciences. *IBM Systems Journal: Service Science, Management and Engineering, 47*(1), available at http://www.research.ibm.com/journal/sj/471/larson.html

Pine, B.J. & Gilmore, J.H. (1999). *The Experience Economy: Work Is Theater & Every Business a Stage*. Cambridge: Harvard Business School Press.

Sampson, S.E. (2001). *Understanding service businesses: Applying principles of Unified Services Theory* (2nd ed.). New York: Wiley.

Sampson, S.E. (December, 2004). *The Unified Services Theory*. Paper presented at the 1st Production and Operations Management Society, College of Service Operations Meeting, Columbia University, New York.

Spohrer, J., Maglio, P., Bailey, J., & Gruhl, D. (2007). Steps toward a science of service systems. *IEEE Computer*, 71-77.

Teboul, J. (2007). *Service is front stage: Positioning services for value advantage.* Insead Business Press.

Terrill, C. & Middlebrooks, A. (2000). Market *Leadership Strategies for Service Companies, Creating Growth, Profits, and Customer Loyalty,* Chicago, IL: NTC Business Books.

Tien, J.M., & Berg., D. (2003). A case for service engineering. *Journal of Systems Sciences and Systems Engineering, 12*(1), 13-38.

Succeeding through service innovation: Developing a service perspective on economic growth and prosperity. (2007). Cambridge Service Science, management and Engineering Symposium (July 14-15, 2007), Møller Centre, Churchill College, Cambridge, UK. Available at: http://www.ifm.eng.cam.ac.uk/ssme/

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